Letter of intent to submit a proposal to the Climate Variability and Predictability element
(Tropical Biases in Coupled Climate Models)

Proposal title: **Coupled warm bias in the far eastern equatorial Pacific in the NCEP CFS model**

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We propose to test a new hypothesis for the CGCM warm SST bias in the far eastern equatorial Pacific, using the NCEP Coupled Forecast System (CFS) model.

The warm SST/weak cross-equatorial wind bias along the equator in the far eastern Pacific has been a feature of CGCMs since their inception in the early 1990s, and persists in modern models. The equatorial bias is often lumped together with the general tendency of coupled models to have a too-warm southeastern Pacific, which is ascribed to difficulties in simulating boundary layer clouds and the resulting local coupled feedbacks.

We argue here that the equatorial SST bias in the far east is driven by a distinct equatorial coupled dynamics, not principally by the boundary layer cloud problem, and that its correction in the CGCMs may be possible using different methodology than for the subtropics. Further, that the consequences of the equatorial bias on the larger-scale climate are quite different from those of the adjacent stratocumulus cloud region.

We hypothesize a coupled feedback loop in which too-warm equatorial SST east of the Galapagos reduces the meridional SST gradient that drives the observed strong southerly cross-equatorial winds, and that the weakened winds in turn reduce the upwelling and mixing from the shallow thermocline that in the real system efficiently cools SST. All these processes are distinct to the equator, as are the impacts on the larger climate. Since equatorial zonal winds are highly sensitive to the zonal SST gradient, warm-biased SST in the far east contributes to the weakened trade winds seen in almost all the CGCMs. Moreover, since the westward propagation of the annual cycle, which couples zonal winds and SST and which is poorly simulated in most models, is initiated in the far east, the biased SST east of the Galapagos probably plays a role in this model error as well.

The alternative hypothesis is that the equatorial bias is due to the same boundary layer cloud problem as exists further south, amplified by local feedbacks as in the larger stratus region. A third possibility is that problems in the equatorial far east are associated with deficiencies in the simulated Peru upwelling system, advected north. (In reality, all three processes probably contribute to some degree). However, even if clouds or coastal processes are the origin of the bias, the specific equatorial coupled feedback loops and larger-scale consequences described above will still be active, which implies that these mechanisms can amplify an initial perturbation initialized somewhere else. Therefore, improving the coupled simulations requires a careful diagnosis of this element of the system, beyond the role of clouds. As in other areas of climate, equatorial dynamics has a unique potential that can amplify and spread an initial perturbation.

The proposed work will test these hypotheses in the NCEP CFS model, which produces biases similar to those seen across the latest generation of CGCMs. In addition, other coupled model runs in the PCMDI/CMIP collection are available for comparison. We will evaluate the mechanisms and determine the origin of the eastern equatorial warm bias and the corresponding wind signals, in the ocean, the lower atmosphere, or the coupling, and estimate the magnifying role of coupled feedbacks. We will diagnose the eastern initiation of the coupled westward-propagating annual cycle to identify the downstream implications of incorrect simulation of eastern equatorial processes and meridional winds. If our simple hypothesis is correct, it points to specific measures to fix the models.

Work elements to be accomplished:

1. Use observations to document the detailed structure of the equatorial warm SST/cross-equatorial wind bias compared to the CFS simulation, and its association with the other bias signals in the eastern Pacific. NCEP has an ongoing program to assess the CFS against observations (directed by Xue), and we will augment this effort by using high-resolution TMI SST, QuikSCAT surface winds, and Argo profiles to examine observational case studies of the processes as the coupled feedbacks occur. Such analyses will identify the distinctly equatorial dynamics involved, for example the role of the cross-equatorial upwelling cell produced by meridional winds in generating cool SST just south of the equator.
2. Examine forced ocean-only and atmosphere-only runs of the CFS component models, in comparison to the coupled model, to evaluate the signatures produced along the equator in relation to those of the larger eastern region, and to isolate the mechanisms to the component models or to the coupling. These studies will also examine the sequencing of SST and wind changes, within the annual and ENSO timescales, to describe and diagnose the series of events that lead to the observed bias, which will provide clues as to their origins and point to directions for their correction.
3. Compare the NCEP CFS model to other state of the art CGCMs in the PCMDI, to determine the generality of the far eastern processes in these models.
4. Communicate the results within NCEP to enhance their forecast assessment and model development efforts.

All model and observational fields, and computational resources, needed for the study are available to the investigators.

Budget (each of 3 years)

• PI (Kessler, PMEL) (3 months/yr)	NC
• PI (Xue, NCEP) (1 month/yr)	NC
• Contract scientist (Boyin Huang, NCEP) (3 months/yr)	$35 k/yr
• Programmer support (TBA, PMEL) (2-3 months/yr)	$25 k/yr
• Domestic travel (Kessler to NCEP, 1 visit/yr)	$ 2 k/yr
• Domestic travel (Kessler and Xue to Bias workshop or AGU)	$ 3 k/yr
• Publications (1/yr)	$ 3 k/yr
Total/yr	$68 k/yr

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